WHOLE COTTONSEED FED FREE-CHOICE TO BEEF COWS DURING WINTER, AND DIGESTIBILITY OF COTTONSEED DIETS BY BEEF STEERS[1]

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ABSTRACT

In a 2-yr study, non-lactating, non-pregnant beef cows were fed bermudagrass hay free-choice on six dormant bermudagrass pastures, and supplemented with three levels of whole cottonseed: 0.25% of BW (Low WCS), 0.5% of BW (Med WCS), or free-choice (FC WCS) for 63 d beginning November 3, 2005, and for 70 d beginning October 5, 2006. Cows were fed hay free-choice in hay rings in each pasture. The DMI of WCS, hay and total diet (kg) on Low WCS, Med WCS, and FC WCS treatments, respectively, were: 1.4c, 9.5b, 10.9b; 2.4b, 11.5a, 13.9a and 4.1a, 10.4ab, 14.4a; within WCS, hay or diet, means with uncommon letters differ ($P < 0.01$). The ADG for cows in 2006 was adjusted to 63 d, and the 2-yr 63-d ADG was higher for FC WCS than Med or Low WCS (ADG kg, 0.59 vs. 0.45 and 0.36, $P < 0.05$). In 2006, serum total gossypol and the (-) isomer (ug/ml), respectively for Low WCS, Med WCS, and FC WCS on d 42 and d 62, were: 0.88, 0.35, and 0.70, 0.33; 1.34, 0.62, and 1.05, 0.48; 1.62, 0.75, and 1.05, 0.51. With increased WCS fed on Med and FC WCS treatments, serum gossypol increased, including the (-) isomer that is associated with increased gossypol toxicity. In a related study, large 2-yr old beef steers were selected to simulate effects of feeding mature beef cows varying levels of whole cottonseed WCS with hay. Steers (n=28; initial BW 456.5 kg; breeding, AN X PH) were fed dietary treatments composed of: 1) Hay with no WCS, (H); 2) hay with WCS fed at 0.25% BW daily (Low WCS); 3) hay with WCS fed at 0.5% BW daily (Med WCS); or 4) hay with WCS fed free-choice (FC WCS). The DMI of WCS, hay and total diet (kg) on H, Low WCS, Med WCS, and FC WCS treatments, respectively, were: 0.0d, 5.92a, 6.18c; 1.24c, 5.25b,6.49c; 2.30b, 5.23b, 7.53b; 3.68a, 4.50c, 8.18a; within WCS, hay or diet, means with uncommon letters differ ($P < 0.01$). The apparent digestion (%) of OM, ADF, and NDF of H, Low WCS, Med WCS, and FC WCS diets, respectively, were: 75.0a, 68.6a, 75.3a; 75.0a, 68.4a, 75.0a; 73.7ab, 67.1ab, 73.3ab, 62.7,b, 53.3b, 61.1b; within OM, ADF or NDF means with uncommon letters differ ($P < 0.01$). The steer digestibility results show that total dietary OM and fiber digestibility were depressed for the FC WCS treatment. Results of the 2-yr cow experiment and the digestion experiment strongly suggest that beef cows should not be fed WCS free-choice, because of negative impact on economics, diet digestibility, and possible animal health and reproductive performance.

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INTRODUCTION

Whole cottonseed have become a very popular by-product feed for wintering beef cows in the Southern USA. The product is locally available to many producers across the region. Over time, ruminant nutritionists have recommended that cottonseed should be fed at about 0.5% of average body weight (BW), or about 2.3 to 3.2 kg/cow daily (Rogers et al., 2002). Cottonseed provides both energy and protein (96% TDN and 23% CP, NRC, 1996; Feedstuffs, 2001). Research has indicated that cottonseed has a value similar to a 20% CP mixture of corn and soybean meal (Poore and Rogers, 1998). Beef cows can utilize cottonseed and hay very well, but younger growing cattle had diminished performance on cottonseed/hay diet compared with a corn/cottonseed meal diet (Hill et al., 2003; 2004), and performance decreased when cottonseed were fed at greater than 15% of diet DM in heifer diets (Poore, 1994). Feeding cottonseed at dietary levels higher than 0.5% of cow BW will supply excess fat in the diet, which could interfere with fiber digestion of the hay being fed. While ruminants have a fairly high tolerance for gossypol in cottonseed, excessive feeding of cottonseed could cause devastating effects on metabolism and health of cows. Nevertheless, some producers attempt to self-feed cottonseed, without actual knowledge of what intake levels may be, without regard to wasted money spent on cottonseed that was not consumed because it was trampled, refused because of being wet after rains, and not efficiently utilized because of over-consumption. Cottonseed bought in bulk at the gins in autumn at harvest ranged from $65/t to $95/t, in South Georgia in 2005-2006 with increasing prices during winter and spring. In October, 2007, cottonseed were priced at $150/t to $180/ton at the same gins, and on January 9, 2008, the FOB price at Memphis, TN, was quoted at $252/t. Few could afford to self-feed the product at these prices without knowledge of expected DMI.

After decades of feeding trials and producer usage of cottonseed as a supplement, few if any documented research trials have been conducted to determine how much cottonseed mature cows will consume. So, the question was asked, how much cottonseed will mature beef cows consume? The question became more critical with significantly increased actual costs of cottonseed in 2007-2008. Therefore, experiments were designed to determine free-choice intake of cottonseed by beef cows during winter, and the effects on diet digestibility when cottonseed was fed at recommended levels and free-choice.

MATERIALS AND METHODS

Cows and Treatments

In the 2-year study, non-lactating, non-pregnant beef cows [42 cows/yr; no. cows/breed, for 2005, 2006, respectively; Angus (AN), n=12, 20; Polled Hereford (PH), n=6, 3; Brangus (BRA), n=16; 21; Braford (BRF) n=8, 7] were fed bermudagrass hay (Table 1) free-choice on six dormant bermudagrass pastures (0.89 ha each), and supplemented with three levels of whole cottonseed: 0.25% of BW (Low WCS), 0.5% of BW (Medium WCS), or free-choice (FC WCS) for 63 d beginning November 3, 2005, and for 70 d beginning October 5, 2006. Cows were fed hay free-choice in hay rings in each pasture. Cows were ranked by BW within breed type and stratified by cow age in six outcome groups. The six groups were then randomly assigned to three dietary treatments. Initial and final BW were averages of consecutive daily full weights, and cows were assigned visual body condition scores (BCS; scale 1 to 9; 1=emaciated; 9 =obese) on d 1 and the last day of each experiment. Rib fat and rump fat depths were measured by ultrasound on d 1 of each experiment, and within the final week of supplementation. A commercial mineral containing at least 8% P and salt (Beef 8®, W.B. Fleming Co., Tifton, GA) was available free-choice to all cows. Hay disappearance was closely monitored, WCS intake was measured on a daily basis. All cows and steers were managed under procedures approved by the University of Georgia Animal Care and Use Committee Guidelines.

In the 2006 study, each cow was bled via jugular veinipuncture on d 42 and d 69; serum samples were analyzed gossypol, and plasma was analyzed for lipids. A Bayer Advia 1200 Chemistry System (Siemens Medical Solutions Diagnostics, Tarrytown, NY) was used to analyze plasma samples for plasma urea nitrogen (PUN / Direct analysis), cholesterol (CHO; cholesterol / HDL), high-density lipoprotein (HDL), and triglycerides (TRIG). Cholesterol, TRIG, and D-HDL were measured directly. The low-density lipoprotein (LDL) was calculated using the formula: Total Cholesterol - (HDL [triglycerides/5]). Hay and WCS consumption were closely monitored each year. Hay and cottonseed were periodically sampled and chemically analyzed (Table1) for DM and CP using AOAC (1990) procedures, and ADF and NDF were determined using methods outlined by Van Soest et al. (1991). Cottonseed were chemically analyzed for nutrients other than gossypol by Dairy One Laboratories, Ithaca, NY. The concentration of gossypol in serum was determined by forming a Schiff's base complex between gossypol and R-(-)-2-amino-1-propanol (CAS #35320-23-1). This complex was separated by reverse-phase HPLC, and then detected and quantified by UV absorption at 254 nm. The method has similarities to the procedure of Hron et al. (1999) for the measurement of gossypol in cottonseed and cottonseed meal.

Steer Dietary Intake and Digestion Experiment

In 2006, large beef steers approximately 2 years of age were selected to simulate effects of feeding mature beef cows varying levels of whole cottonseed (WCS) with hay. Steers (n=28; initial BW 456.5 +/- 38.8 kg; breeding, AN X PH) were fed dietary treatments composed of: 1) Hay with no WCS; 2) Hay with WCS fed at 0.25% BW daily (Low WCS); 3) Hay with WCS fed at 0.5% BW daily (Med WCS); or 4) Hay with WCS fed free-choice (FC WCS). Steers were individually-fed Tifton 85 hay (Table 1) free-choice with treatment supplements for 17 d, and feed intake and feed refusals were recorded. Chromic oxide (10 g/steer daily last 10 days of trial) was fed as an indigestible marker in each experiment. Fecal samples (11/steer over last 5 days of each experiment) were collected, dried, ground through a 1 mm screen, and submitted for nutrient content and chromic oxide analyses to determine apparent digestion of organic matter, crude protein and fiber digestibility. Nutrient and fecal analyses were conducted using the same procedures described for cow diets.

Statistical Analyses

The cow performance data (BW, ADG, BCS, and ultrasound fat depth) were analyzed using Proc MIXED (SAS, 2002). The covariates listed in Table 3 were used to center 2-yr average cow performance data. Cow breeds included AN, PH, BRA, and BRF, and two Breed Types were designated: Breed Type 1= AN and PH; Breed Type 2= BRA and

BRF. Cow Breed Type, cow age, initial BW, final BW were used to adjust BCS data. Steer intake and digestion data were analyzed using Proc Mixed (2002), with hay DMI adjusted for steer BW as a covariable, and steer weight class and steer BW did not affect apparent digestion coefficients.

RESULTS AND DISCUSSION

In each year, cows were assigned to treatments in autumn, and fed hay with three levels of WCS. Cows were in good body condition and health. Hay and WCS analyses for multiple samples of each feed source are shown in Table 1. The WCS had typical CP and fat content for Southeastern cotton, but TDN values were below many published values. These analyses were conducted by Dairy One Laboratories, Ithaca, NY, and the formulas they use to compute TDN consistently result in lower TDN values for WCS than other laboratories. Bermudagrass hay contained approximately 11 % CP (Table 1), typical, but higher than the average bermudagrass hay produced in the region. Hay was harvested using conventional disc mowers and round balers, and hay was stored outside, which is the usual practice followed by many Southeastern beef producers. The hay alone would meet the protein requirements of dry beef cows (NRC, 1996), and supplemental WCS insured no deficiencies.

The 2-yr intake of WCS and hay (Table 2), and similar intake occurred in each year for the FC WCS treatment. The level of WCS was held constant at 0.25% or 0.5% of cow initial BW during the experiment for Low WCS and Med WCs treatments. Hay disappearance was greatest ($P < 0.01$) for cows on the Med WCS treatment, intermediate for FC WCS, but lowest for the Low WCS. This data suggests that feeding WCS at the recommended level of 0.05% BW actually stimulated hay intake. The WCS intake (Table 2) indicated that cows consumed substantially higher daily amounts of WCS on the FC treatment than on Low or Med WCS treatments, as expected, since WCS intake was limited on the Low and Med WCS treatments. The FC cows consumed cottonseed at 4.06 kg DM/d (8.93 lbDM/cow; 9.81 lb/d WCS as-fed). Based on fat content of the WCS, this resulted in FC WCS cows consuming 0.73 kg fat/d (1.61 lb fat/cow daily), which was a huge amount of fat to be metabolized by ruminal microbial populations. Interestingly, cows on the FC WCS treatment had the highest total DMI, with both Med WCS and FC WCS having similar, but higher ($P < 0.01$) total DMI than cows on the Low WCS treatment. This occurred from the stimulation of hay intake by feeding WCS on the Med WCS and FC WCS treatments, added to the substantial consumption of WCS by FC c WCS cows. No noticeable diarrhea or adverse effects of high WCS consumption on FC WCS were noted in either year of the study. However, intake patterns were different for each pen of cows on the FC WCS treatment each year (Figure 1). The figure shows constant intake of WCS for Low and Med WCS treatments, which were averaged for the two pens of cows each year. However, cows on FC began the study at the Med WCS level, and were challenged with increased WCS offered every two days until intake leveled off after six weeks each year. By d 28 each year, WCS intake was above 5 kg DM/cow daily (> 11 lb/cow, as-fed) for each replicate of the FC WCS treatment. In each year, one replicate of cows had decreased WCS intake by d 42, but the other replicate continued to consume high levels of WCS. In 2005, one FC WCS replicate dropped to about 4.75 kg/d after d 28, and was below the WCS intake of Med WCS cows by d 56;

however, the other FC WCS replicate continued to consume WCS at levels greater than 5.0 kg/d from d 21 to d 63. In 2006, similar intake patterns occurred compared with 2005, but both FC WCS replicates dropped under 5.0 kg WCS daily after d 28. Then, as in 2005, one replicate remained at about 4.5 kg WCS daily through d 56, before dropping to 3.0 and 3.5 kg/d at d 63 and d 70. The other replicate dropped from 5 kg/d at d 28 to about 4.5 kg/d at d 35 and d 42, then declined further to about 2.0 kg/d by d 49 and d 56. These FC WCS cows had increased WCS intake during the final two weeks, increasing to about 3.4 kg/d at d 63 and d 70. Therefore, some cows on the FC WCS treatment experienced aversion to WCS after experiencing very high (> 5.0 kg/cow daily) WCS intake. During these intervals, hay intake was not observed to increase in any measurable amounts for the replicates experiencing declining WCS intake. It is interesting to note that in 2005, one replicate continued to consume > 5.0 kg WCS/day until the experiment ended, but the other replicate never regained previous intake. In 2006, one replicate remained around 4.5 kg/d after d 28, but one replicate dropped dramatically, and neither replicate rebounded to d 56 levels. Therefore, results suggest that free-choice feeding of WCS to beef cows could lead to erratic intake in herds of cows, and that there is apparently a difference in tolerance and metabolism of cows fed higher levels of fat, fiber, and protein.

Cow performance was affected by WCS supplementation of hay-based diets (Tables 3 and 4). In Table 3, means of various factors used as covariates to adjust performance and body fat least squares means. Cows used in the study were older ($P < 0.05$) and heavier ($P < 0.01$) in 2006 than in 2005, but US rib fat, US rump fat, and BCS were similar for cows each year. Cow ADG, change in rib fat depth, and change in rump fat depth were affected by year of the study. More 3- and 4-year-old cows that had lower BCS were used in 2005 than 2006, resulting in higher overall gain of cows in 2005. With the increased WCS consumption by FC WCS cows, and their higher ($P < 0.01$) total DMI (Table 2), these cows had higher ADG than Low WCS or Med WCS cows. The change in US rib fat depth was greatest ($P < 0.05$) for FC WCS, intermediate for Med WCS, and lowest for Low WCS, with actual losses of rib fat recorded for cows on Low WCS. Rump fat depth change was higher ($P < 0.\ 01$) for Med WCS and FC WCS cows than for Low WCS cows. A Breed Type X cow age interaction ($P < 0.10$) affected cow ADG and cow rib fat depth change (Table 4). For cows less than three years of age, Breed Type 2 cows had higher ADG than Breed Type 1 cows ($P < 0.05$), but breed type did not affect cow ADG of cows that were greater than four years of age. Additionally, Breed Type 2 cows that were less than three years of age had higher ADG than cows that were greater than 4 yr of age, indicating more compensatory gain in the younger Breed Type 2 cows. The Breed Type X Cow age interaction for change in rib fat (Table 4) shows similar rib fat change increases for cows less than 3 yr of age of each breed type, but a marked depression of rib fat depth for Breed Type 2 cows that were greater than four years of age. While ultrasound data was based upon a specific cross section site for fat depth over the rib and rump, BCS values reflected visual appearance of the cow along back, rib, rump and brisket. The BCS data (Table 5) indicated that cows had similar initial BCS on each treatment in each year. In 2005, final BCS scores were higher ($P < 0.05$) for Med WCS and FC WCS cows than for Low WCS cows, and Low WCS cows had lower final BCS than initial BCS, indicating a loss of condition on this treatment. In 2006, final BCS was greater than initial BCS for all treatments, however greater ($P < 0.01$), final BCS were recorded for Med WCS and FC WCS.

The effects of level of WCS fed on serum gossypol and plasma lipids are shown in Table 6. Cows were bled on d 42 and d 69 in the 2006 study, with FC WCS having WCS intake greater than 4 kg/d on d 42, and approximately 3.8 g/d by d 70 (Figure 1). At d 42, total serum gossypol was 46% higher for FC WCS than Low WCS, and 17% higher for FC WCS than Med WCS (Table 6). Similarly, the (-) isomer of serum gossypol on FC WCS was more than twice the concentration observed on Low WCS. At d 69, total serum gossypol was 33% higher for Med and FC WCS than Low WCS, and the (-) isomer concentrations followed a similar pattern. All serum gossypol values were probably mediated by absorption, liver activity, digestion processes and dilution by the hay diet. Nevertheless, at d 42 when FC WCS intake was highest, total serum gossypol and the (-) isomer concentrations were substantially elevated. Although WCS intake was approximately 3.8 kg/d for each replicate of the FC WCs treatment by d 69 (Figure 1), serum total and (-) isomer gossypol concentrations were similar for Med and Fc WCS (Table 6). Although not as severe in 2006 compared with 2005, WCS intake declined on the FC WCS treatment. The apparent aversion for WCS observed for one replicate in 2005 might have been caused by toxic effects of gossypol in the very high consumption until d 42 (Figure 1). However, cows in both years did not show usual clinical signs of toxicity outlined by Rogers et al., (2002), and total DMI was similar for Med and Fc WCS treatments (Table 2). Virtually all of the gossypol in WCS is in the free form, so free and total gossypol values for WCS should be almost identical (Pons et al., 1953). The free form is toxic, but the bound form is not because it usually is not released in the rumen. Futhermore, the (-) isomer of gossypol apparently has the most biological activity, and it is responsible for the toxic effects of gossypol (Rogers et al., 2002).

With the substantially higher levels of CP and crude fat consumed by FC WCS cows, one would expect higher PUN and blood lipid concentrations. The PUN was similar at d42 and d 69 for Med and FC WCS treatments, each of which was higher than Low WCS (Table 6). The hay CP and the slower release of ammonia from the WCS probably increased PUN on the Low WCS treatment to levels about 20% lower than Med and FC WCS. The increased WCS consumption did not raise PUN values for FC WCS substantially above Med WCS. Plasma CHO was higher for Med and FC WCS than Low WCS on both sampling dates (Table 6). Although triglyceride and HDL were not affected by treatment, LDL increased for Med and FC WCS treatments compared with Low WCS. While increased CHO resulting from fat supplementation has been associated with increased reproductive performance, a trend was observed for lower plasma CHO on FC WCS compared with Med WCS. The slower release of fatty acids from WCS, better balance of fiber, protein and fat, and the increased dietary fat on Med WCS might have increased plasma CHO. Long et al. (2007) reported increased serum CHO when beef heifers were supplemented with a rumen protected fat source fed with corn gluten feed on pasture before breeding.

In 2006, heavy steers similar in weight to many beef cows were used to determine total tract digestibility of the WCS fed in fed diets similar to those in the cow experiments. In the steer experiment (Tables 1) hay crude protein and quality was somewhat higher than feeds used in the cow experiments, and hay averaged above 14% CP, well above CP requirements for the steers. Hay DMI was reduced with increasing

WCS intake across treatments (Table 7), with the lowest hay DMI on the FC treatment. In Table 7, WCS intake was highest (*P* < 0.01) for FC WCS intermediate for Med WCS , and lowest for Low WCS, resulting from feeding the three levels of WCS. Total diet DMI was highest for FC (*P* < 0.01), intermediate for Low and Med WCS, and lowest for H. Total DMI and WCS DMI, especially on FC WCS was affected by the short duration of the steer digestion experiment. If Figure 1 from the cow study is examined, it indicates that cows fed WCS FC had increasing WCS intake for at least 6 weeks before declining. Therefore, it is remarkable that steers on FC WCS consumed the levels indicated in Table 7 by the end of the 17-day experiment, and intake was increasing at the end of the experiment. Most steers on FC WCS were consuming about the same amount of WCS, with little evidence of aversion. The OM, ADF and NDF digestibility coefficients were greater (*P* < 0.01; Table 7) for Hay Only and Low WCS than for FC, and intermediate for Med WCS. Interestingly, CP digestibility increased (P < 0.01) for Med WCS, but declined for FC WCS to the same level as H. The ether extract percentage of diets increased dramatically from 2.1 to 7.6 % across the four treatments, which probably decreased OM and fiber digestibility. Steers on the FC diet had reduced DMI and severely reduced OM and fiber digestibility. In a similar study using 2-yr old steers and the same dietary treatments as in this study, Hill et al. (2007) reported depressed OM and fiber digestion for the FC WCS treatment, although FC WCS steers did not attain the level of WCS consumption reported in the present study. These results further underscore the contention that cows will consume more WCS than many producers believe they will consume, resulting in economic losses and decreased efficiency in digestibility of hay and WCS. Although cows on FC WCS had numerically higher total DMI (Table 2), higher ADG (Table 4; *P* < 0.05), both OM and fiber (ADF and NDF) digestion were diminished when steers were fed the DC WCS diet.

CONCLUSIONS

Results of the 2-yr cow feeding experiment and the steer digestion and intake study add to our knowledge related to WCS feeding to cattle. The cow experiment indicate that mature cows will consume far more WCS than the recommended amount, approaching 4.06 kg/cow daily on a DM basis. At the current price of $252/ton (FOB, Memphis, TN), this would be cost prohibitive. This indicates that producers often underestimate the amount of WCS cows may consume if offered free-choice, and with the 2007-2008 price increases, free-choice feeding becomes prohibitive. Although cows gained more weight on the free-choice WCS treatment, the steer digestion trial clearly indicates that total diet digestibility of OM and fiber were reduced for the FC treatment. Blood gossypol data showed large increases in serum total gossypol and the (-) isomer of gossypol for non-pregnant cows in this study on the free-choice WCS treatment, which could have implications for reproduction and long-term health of pregnant heifers or cows and nursing cows. Therefore, the recommended level of WCS supplementation at 0.5%BW for beef cows appears to be the best alternative when economics, diet digestibility, and animal health are considered.

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Table 1. Chemical composition of hay and WCS fed to cows and digestion trial steers.

Item	DM	CP	ADF	NDF	Fat	TDN, %
	------------------------% DM Basis------------------------------					
Cottonseed						
Cows-2005	92.5	22.4	39.2	54.7	18.0	72
Cows-2006	91.8	24.6	42.6	57.6	17.7	71
Steers-2006	91.1	25.9	49.9	67.4	15.0	74
Hay						
Cows-2005	91.5	11.3	55.7	78.4	1.4	53
Cows-2006	92.4	10.5	40.0	76.2		54
Steers-2006	91.1	13.7	41.0	74.5	1.9	

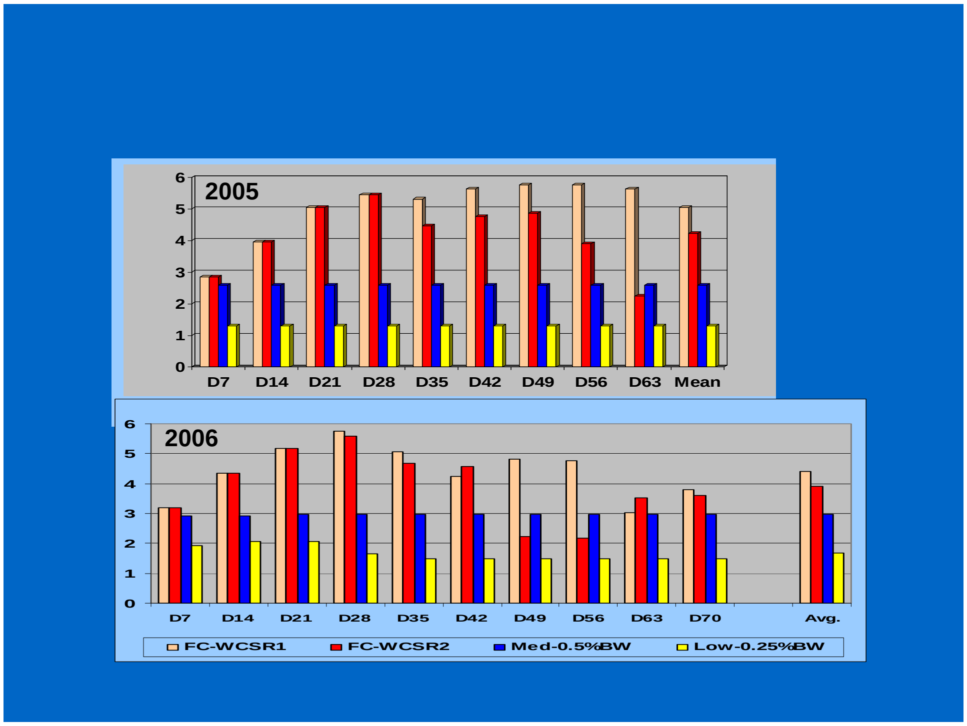

Figure 1. Weekly intake by cows of cottonseed (WCS) fed at 0.25% BW, 0.50% BW or free-choice [2-yr as-fed basis, kg/d; showing intake for each replicate for cows on free-choice (FC) WCS: FC-WCS R1 =Rep 1; FC-WCS R2 =Rep 2].

Table 2. Two-year average hay disappearance and whole cottonseed consumption by cows (2005, 2006).

Item	Low WCS 0.25%BW	Med WCS 0.50% BW	High WCS Free-Choice	SE
No. cows/Trt each yr	14	14	14	
Disappearance of Hay, kg/d	9.48^{b}	11.50^{a}	10.36^{ab}	0.38
WCS DMI, kg/d	1.41^{b}	2.41^{b}	4.06^{a}	0.24
WCS fat intake, kg	0.25	0.43	0.73	
Total DMI, kg/d	10.90^{b}	13.91^{a}	14.42^{a}	0.42

Abbreviations: WCS = Whole cottonseed; Trt=Treatment.
^{ab}Means with different superscript letters differ ($P < 0.01$).

Table 3. Covariates used to center 2-yr average cow performance when cottonseed was fed at three levels with hay.

	2005	2006	
Covariate	Mean +/-SD	Mean +/-SD	*t* value
Initial BW, kg	517.4 +/- 99.2	578.9 +/- 78.4	3.15*
Cow age, yr	3.67 +/- 1.87	6.33 +/- 2.88	5.02**
Initial BCS (1-9)	4.5 +/- 1.11	4.5 +/- 0.81	0.00
Initial US ribfat, cm	0.60 +/- 0.43	0.78 +/- 0.27	2.30
Initial US rump fat, cm	0.55 +/- 0.61	0.51 +/- 0.22	0.40

Table 4. Cow ADG and ultrasound fat changes with breed type X cow age interactions.

Item	2005	2006	SE	Low WCS	Med WCS	High F C WCS	SE
ADG, kg	0.54^{x}	0.43^{y}	0.05	0.36^{r}	0.45^{r}	0.59^{q}	0.04
Change USF rib fat, cm	-0.06^{b}	0.15^{a}	0.04	-0.08^{r}	0.07^{q,s}	0.14^{q}	0.05
Change USF rump fat, cm	0.01^{b}	0.32^{a}	0.05	0.04^{b}	0.21^{a}	0.25^{a}	0.04

Breed Type X Cow Age Interactions

	Cow Age	Breed Type 1 AN & PH	Breed Type 2 BRF & BRA	SE
ADG, kg	< 3 yr	0.44^{r}	0.63^{q}	
	> 4 yr	0.41	0.44^{r}	0.07
Change Rib USF, cm	< 3 yr	0.01	0.07	
	>4 yr	0.12^{r}	-0.02^{q}	0.05

$^{a\ b}$ Means bearing different superscript letters differ ($P < 0.01$).
$^{q\ r\ s}$ Means bearing different superscript letters differ ($P < 0.05$).
$^{x\ y}$ Means bearing different superscript letters differ ($P < 0.10$).

Table 5. Cow BCS for cows supplemented with cottonseed in 2005 and 2006.

Item	Year	Low WCS 0.25%BW	Med WCS 0.50% BW	High WCS Free-Choice	SE
Init BCS^{k}	2005	4.61	4.46	4.44	0.14
Fin BCS^{l}		4.31^{y}	4.92^{x}	4.91^{x}	0.12
Init BCS^{m}	2006	4.58	4.51	4.36	0.26
Fin BCS^{n}		4.70^{b}	5.26^{a}	5.31^{a}	0.11

$^{a\ b}$ Means bearing different superscript letters differ ($P < 0.01$).
$^{x\ y}$ Means bearing different superscript letters differ ($P < 0.05$).
^{k}Initial BCS covariate adj: breed type ($P < 0.06$), cow age (P<0.07), initial BW ($P < 0.01$)
^{l}Final BCS covariate adj: initial BW ($P < 0.05$), Initial BCS (P<0.01)
^{m}Initial BCS covariate adj: breed type X Trt ($P < 0.20$), initial BW (P < 0.01)
^{n}Final BCS covariate adj: initial BCS (P<0.01), initial BW ($P < 0.01$).

Table 6. Serum gossypol and plasma lipids in cows fed three levels of whole cottonseed

Item[a]	Low WCS 0.25%BW	Med WCS 0.50% BW	High WCS Free-Choice
No. cows	14	14	14
Serum gossypol	------------------------ ug/ml -----------------------------		
D 42 Total (% + isomer)	0.88 (55.2)	1.34 (54.6)	1.62 (54.94)
+ isomer	0.44	0.74	0.92
- isomer	0.35	0.62	0.75
D 69 Total (% + isomer)	0.70 (54.5)	1.05 (54.1)	1.05 (51.2)
+ isomer	0.39	0.56	0.54
- isomer	0.33	0.48	0.51
Plasma components	-----------------------mg/dl--------------------------------		
D 42			
Plasma urea nitrogen	12.93	15.21	15.63
Cholesterol	183.57	226.00	207.96
Triglyceride	24.07	23.64	23.24
High-density lipoprotein	83.21	96.57	93.19
Low-density lipoprotein	94.42	124.21	110.07
Cholesterol / HDL	2.21	2.35	2.26
D 69			
Plasma urea nitrogen	13.14	15.00	15.43
Cholesterol	193.57	231.07	218.64
Triglyceride	34.93	30.79	32.57
High-density lipoprotein	89.29	94.93	94.43
Low-density lipoprotein	97.43	130.14	117.64
Cholesterol / HDL	2.16	2.44	2.33

[a] Table contains raw means without statistical analyses.

Table 7. Steer DMI of dietary components and apparent digestibility by steers.

Item	Hay	Low WCS, 0.25% BW	Med WCS, 0.50% BW	High WCS, Free-choice	SE	*P* <
	----------------------------DMI, kg -------------------------------					
Hay	5.92^{a}	5.25^{b}	5.23^{b}	4.50^{c}	0.12	0.01
WCS [d e]	-----	1.24^{c}	2.30^{b}	3.68^{a}	0.10	0.01
Total	6.18^{c}	6.49^{c}	7.53^{b}	8.18^{a}	0.12	0.01
	--------------Total diet apparent digestibility, % ---------------					
OM, %	75.0^{a}	75.0^{a}	73.7^{ab}	62.7^{b}	1.15	0.01
CP, %	80.3^{b}	81.6^{ab}	82.5^{a}	80.2^{b}	0.60	0.01
ADF, %	68.6^{a}	68.4^{a}	67.1^{ab}	53.3^{b}	1.58	0.01
NDF, %	75.3^{a}	75.0^{a}	73.3^{ab}	61.1^{b}	1.34	0.01

[abcd] Means bearing different superscript letters differ ($P < 0.01$).

[e] Steers on all treatments were fed corn (0.23 kg/d DM)as a carrier for chromic oxide, and the values for total DMI include this corn.